CLAIMS

1. A method for the automated analysis of a digital image comprising an array of pixels, including the steps of:

5   generating a property co-occurrence matrix (PCM) from some or all of said pixels, using the properties of local mean and local standard deviation of intensity in neighbourhoods of the selected pixels; and

segmenting the image by labelling the selected pixels as belonging to specified classes consequent upon analysis of said PCM.

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2. A method according to claim 1 wherein respective Gaussian distributions are fitted to the two main distributions within the PCM using an implementation of the Expectation Maximisation (EM) algorithm to determine the distribution parameters.

15   3. A method according to claim 1 or claim 2 wherein pixels are labelled in accordance with a distribution within the PCM to which they are closest and including the steps of:

assigning a respective label to separate distributions within the PCM;

determining the normalised distance between the point within the PCM to which 20   the respective pixel contributes and the centre of each labelled distribution; and

assigning to the respective pixel the label of the distribution for which such normalised distance is the shortest.

4. A method according to claim 3 wherein a scale factor is introduced into the 25   normalisation to bias the labelling towards a particular distribution.

5. A method according to any preceding claim wherein certain pixels are excluded from the formation of said PCM consequent upon a local property of such pixels.

6. A method according to claim 5 comprising the steps, preceding the steps defined in claim 1, of:

    forming a grey level histogram from some or all of the image pixels;

    establishing a threshold consequent upon analysis of said histogram; and

5   excluding from the formation of said PCM those pixels which are above said threshold.

7. A method according to claim 6 wherein said threshold is established as the most significant valley above the main peak of the histogram.

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8. A method according to claim 5 comprising the steps, preceding the steps defined in claim 1, of:

    generating a property co-occurrence matrix (PCM) from the image pixels, using the properties of local mean and local standard deviation of intensity in

15   neighbourhoods of the respective pixels and having a higher resolution than the first-mentioned PCM;

    forming a histogram of the local mean by summing along constant local mean for a small range of local standard deviation;

    establishing a threshold consequent upon analysis of said histogram; and

20   excluding from the formation of the first-mentioned PCM those pixels which are above said threshold.

9. A method according to claim 8 wherein said threshold is established as the most significant valley above the main peak of the histogram.

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10. A method according to claim 7 or claim 9 comprising the steps of:

    extending the respective histogram until its number of bins is equal to 2^n where n is the lowest value such that 2^n bins completely contain the histogram and setting the new bins to zero;

30   further extending the respective histogram by 50% on both sides so that it has 2^{n+1} bins and setting the new bins to zero;

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forming a set of n multi-resolution histograms by averaging groups of bins so that successive histograms have $4,8... 2^{n+1}$ bins;

convolving the histogram values at each resolution with an edge operator;

identifying the locations of all peaks and valleys in each resolution by a change in
5   sign of the results of said convolution;

associating each peak and valley in each resolution with the corresponding peak or valley (if any) in the subsequent resolution; and

identifying the main peak and most significant valley, respectively, as that which is present in the highest number of said resolutions.

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11. A method according to any one of claims 5 to 10 wherein the image is also segmented by labelling the pixels which are excluded from the formation of the first-mentioned PCM as belonging to a specified class different from the first-mentioned classes.

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12. A method according to any preceding claim further comprising the step of grouping into blobs contiguous pixels labelled as belonging to the same one of any said class.

20   13. A method according to claim 12 further comprising the step of calculating statistics concerning respective said blobs and filtering the same in accordance with said statistics.

14. A method according to claim 13 wherein said statistics include one or more of:
25   size in one or more axis direction of the array, area, aspect ratio and density of the respective blob.

15. A method according to claim 13 or claim 14 wherein said filtering comprises relabelling the pixels in selected blobs as belonging to the class of the pixels in a
30   respective surrounding blob.

16. A method according to any one of claims 13 to 15 wherein said filtering comprises relabelling the pixels in selected blobs as belonging to a new class different from any aforesaid class.

5   17. A method according to claim 16 further comprising the step of dilating by a specified amount blobs composed of pixels relabelled as belonging to said new class (Cn) into adjacent blobs composed of pixels labelled as belonging to a selected one of the first-mentioned specified classes (Co).

10   18. A method according to claim 17 wherein said dilation comprises the steps of:

creating a new image by assigning pixels of class Cn in the original image to a value of 1 in the new image and assigning all other pixels to 0;

convolving the new image with a two-dimensional Gaussian kernel having a zero mean and a standard deviation set equal to said specified amount and such that the

15   value of the Gaussian is 1 at 1 standard deviation from the mean;

truncating the resultant image so that it contains only the values 1 and 0; and

if a pixel has a value of 1 in the truncated image and is labelled as either class Cn or class Co in the original image, assigning it to class Cn in the original image.

20   19. A method according to claim 17 wherein said dilation comprises repeatedly performing the steps of:

creating a new image by assigning pixels of class Cn in the original image to a value of 1 in the new image and assigning all other pixels to 0;

convolving the new image with a two-dimensional Gaussian kernal having a zero

25   mean and a standard deviation set to a predetermined value (L) and such that the value of the Gaussian is 1 at 1 standard deviation from the mean;

truncating the resultant image so that it contains only the values 1 and 0; and

if a pixel has a value of 1 in the truncated image and is labelled as either class Cn or class Co in the original image, assigning it to class Cn in the original image;

30   whereby said specified amount of dilation is achieved notwithstanding the presence of gaps of not more than L-1 pixels labelled as belonging to a class neither

Co nor Cn between said blobs composed of pixels labelled as belonging to class Cn and said blobs composed of pixels labelled as belonging to class Co.

20. A method according to any preceding claim further comprising the step of calculating a metric as a function of the numbers of pixels labelled as belonging to selected said classes.

21. A method according to claim 20 when appended to any one of claims 17 to 19 wherein said metric is the ratio of the number of pixels labelled as class Cn after said dilation to the sum of the number of pixels labelled as class Cn and the number of pixels labelled as class Co.

22. A method according to any preceding claim for the automated analysis of a digital image of a histological or cytology specimen.

23. A method according to claim 22 wherein the image is of a section of breast tissue.

24. A method according to claim 22 or claim 23 wherein a result of the first-mentioned segmentation is to label selected pixels as belonging to the class of epithelial cells.

25. A method according to any one of claims 22 to 24 when appended to claim 16 or to any other claim when appended to claim 16 wherein said new class is identified as the class of duct cells.

26. A method according to any one of claims 22 to 24 when appended to claim 17 or to any other claim when appended to claim 17 wherein class Cn is identified as the class of duct cells and class Co is identified as the class of epithelial cells.

27. A method according to claim 26 wherein said dilation is over a distance corresponding to a specified number of epithelial cells.

28. A method according to any one of claims 22 to 27 when appended to claim 20 or claim 21 further comprising the step of transforming said metric to an indication of a grade of cancer.

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29. A method according to any one of claims 1 to 21 for the automated analysis of a digital image of a mineral sample.

30. A method for the automated analysis of a digital image comprising an array of
10   pixels, comprising the steps of:

    segmenting the image by labelling respective pixels as belonging to one of two or more classes;

    grouping contiguous pixels of the same class into blobs;

    calculating statistics concerning respective said blobs;

15   relabelling the pixels in selected said blobs as belonging to a different said class;

    dilating selected blobs of one said class into blobs of another said class by a specified amount; and

    calculating a metric which relates the total area covered by the dilated blobs to the total area covered by blobs of a selected class or classes.

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31. A method for the automated analysis of a digital image of a histological specimen of breast tissue comprising an array of pixels, comprising the steps of:

    labelling pixels as representing epithelial cells and duct cells respectively;

    dilating groups of pixels labelled as representing duct cells into adjacent groups
25   of pixels labelled as representing epithelial cells by a specified amount related to the size of an epithelial cell;

    calculating the total number of pixels labelled as representing duct cells after such dilation and the total number of pixels labelled as representing duct cells or epithelial cells;

30   calculating a metric from the calculations in the preceding step; and

    transforming said metric to an indication of a grade of cancer.

32. Apparatus for the automated analysis of a digital image comprising means adapted to perform a method according to any preceding claim.

5   33. A computer program product comprising a computer readable medium having thereon computer program code means adapted to cause a computer to execute a method according to any one of claims 1 to 31.

34. A computer program comprising instructions to cause a computer to execute a
10   method according to any one of claims 1 to 31.